Chapter 2: WATER QUALITY MODELING STUDIES

2.1 Overview

Three DSM2 daily time step 16-year planning studies were run in HYDRO and QUAL based on the proposed operations for the IDS project islands: Webb Tract and Bacon Island. The Delta inflows, exports and island operations used in these studies were provided from the CALSIM II Daily Operations Model (DOM). A basic description of the DSM2 / CALSIM II scenarios is listed in Table 2.1.1.

Table 2.1.1: Summary of DSM2 Studies.

Study	*Basic Study Objective*	*CALSIM II Operational Constraints*
Study 1	No Action Base	D1641
Study 4[1]	Water Supply / EWA / ERP	D1641 / D1643 / EWA & ERP
Study 4b	DOC Resolution Through Circulation	Study 4 with DOC Constraints

1. Study 4 was used to develop fingerprinting results, but no water quality results from study 4 will be presented.

All three studies were based on separate CALSIM II runs. However, CALSIM II's study 4b includes information from DSM2's study 1 and study 4. The interaction between CALSIM II and DSM2 is illustrated in Figure 2.1.1. Study 1 provided the base line DOC concentrations at the urban intakes. Study 4 used fingerprinting information to provide the project island volume - flow relationships that were integrated into CALSIM II in order to constrain project releases to meet the DOC standards consistent with the State Water Resources Control Board (SWRCB) water rights decision D1643. Due to time constraints, study 4 was not used to analyze DOC or EC based on the study 4 CALSIM II operations.

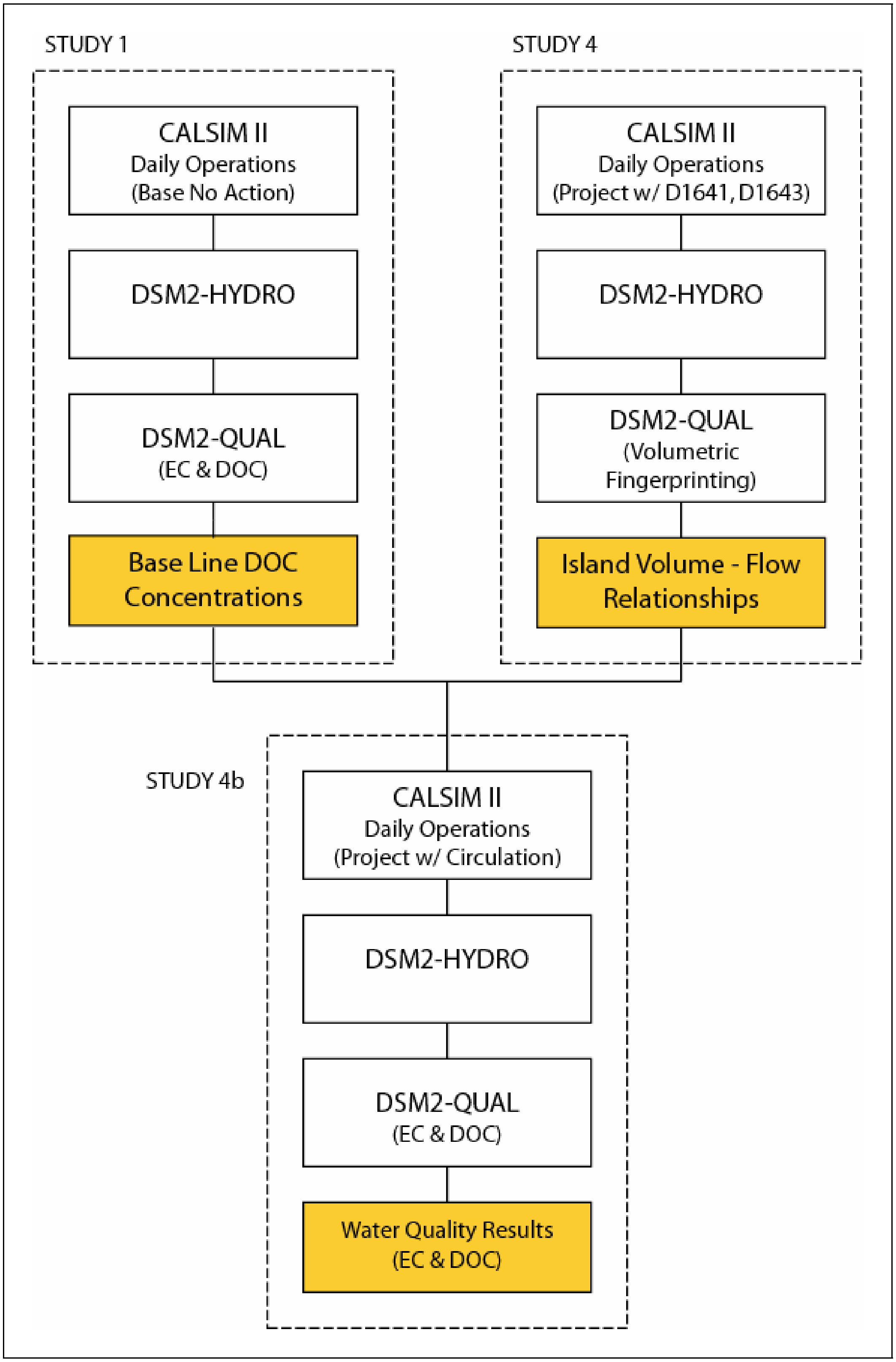

Figure 2.1.1: Study Methodology.

2.2 Delta Hydrodynamics

The major tributary flows, exports, diversions, and operations of the gates and barriers in the Delta affect the hydrodynamics in the Delta. Understanding these hydrodynamics is essential when examining the water quality for any Delta location. The Delta hydrodynamics for all three studies are summarized below. (NOTE: for information related to the operation of the project islands in study 4 and study 4b, see *Section 2.4*.)

2.2.1 Sacramento River and San Joaquin River Inflows

Time series illustrating both the daily average and change in daily average flows (alternative – study 1) for the Sacramento and San Joaquin rivers are shown below. All of the CALSIM II simulations were based on the same hydrology and 2020 level of development demands. The difference between the base and alternative flows and exports was based on how CALSIM II chose to operate the entire system.

For both rivers, the change in daily average flow was calculated as the difference of the base case flow from the alternative. Positive values correspond to periods when the alternative flow was higher than the base case flow. Negative values correspond to periods when the base case flow was higher.

2.2.1.1 Sacramento River

The monthly average difference in Sacramento River Flows for both alternatives (study 4 and study 4b) is shown in Figure 2.2.1. The largest changes in Sacramento flow in April (an increase in Sacramento River flows in the alternatives) and July (a decrease in Sacramento River flows in the alternatives). Since July is a typical project island release month (see *Section 2.4.2.1* for more information about project releases and diversions), this change in Sacramento inflows to the Delta is likely the result of the availability of IDS water to meet SWP and CVP demands.

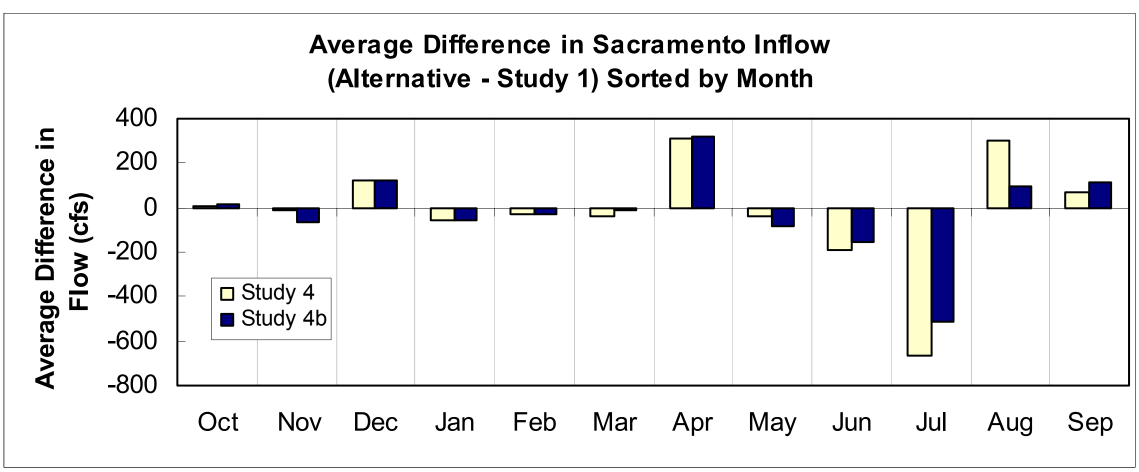

Figure 2.2.1: Difference in Sacramento River Flows (Alternative – Study 1) Stored By Month.

The daily average flows on the Sacramento River (Figure 2.2.2) are highly varied over the course of the 16-year study. The changes in these daily flows due to the operation of the IDS project is illustrated in Figure 2.2.3.

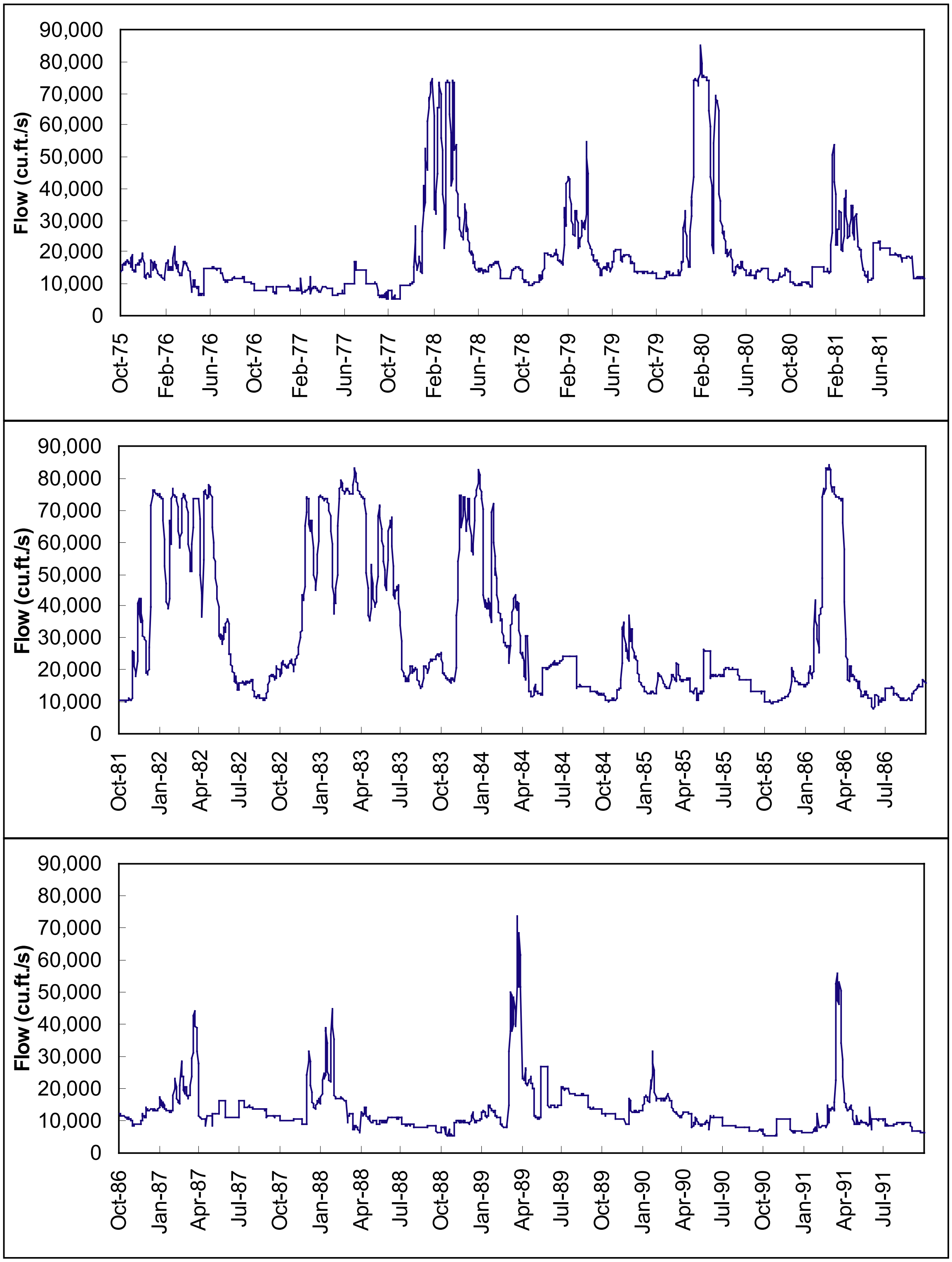

Figure 2.2.2: Daily Average Flow on the Sacramento River for Study 1 (Base).

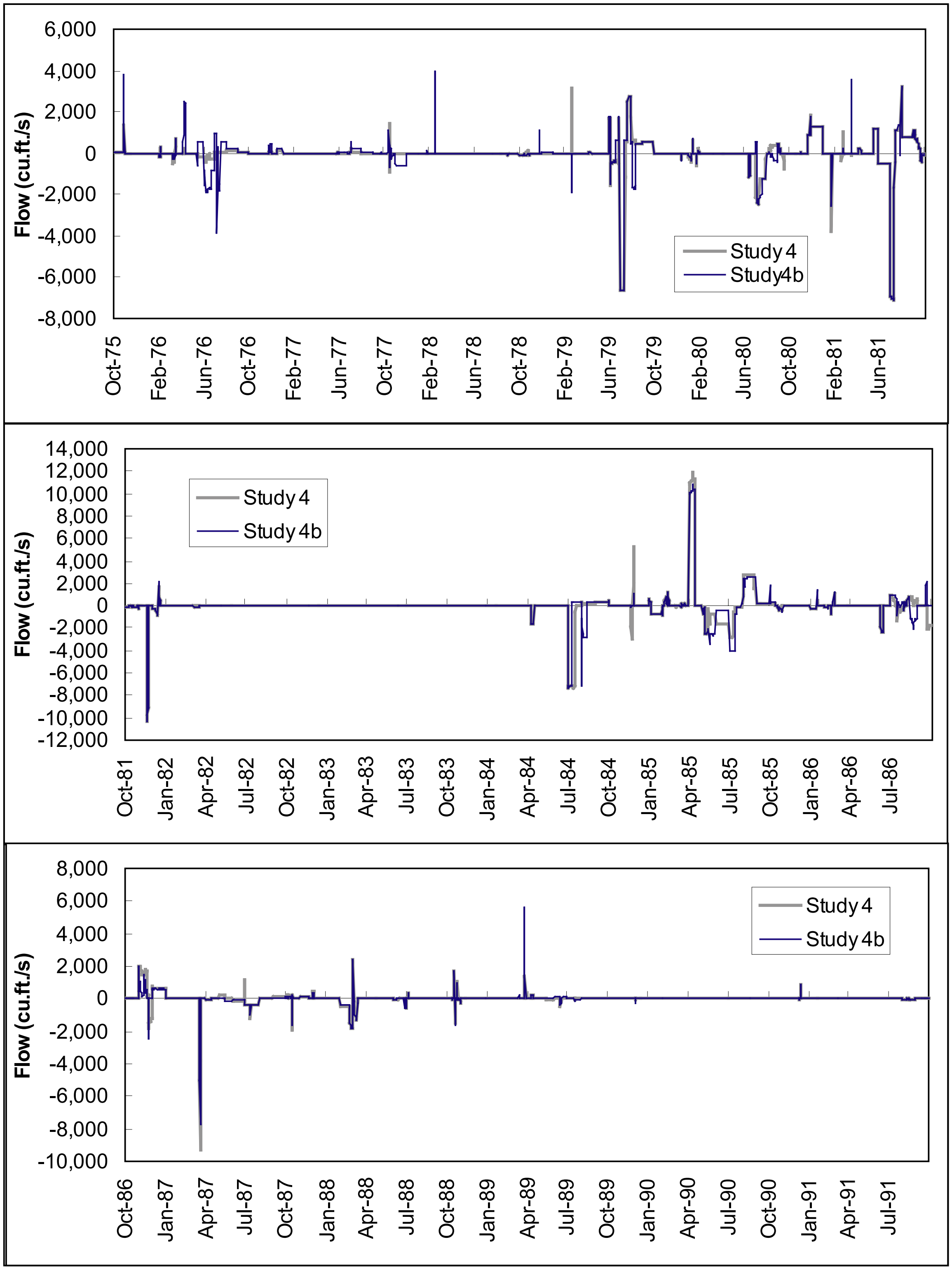

Figure 2.2.3: Change in Daily Average Flow on the Sacramento River due to Study 4 and Study 4b.

2.2.1.2 San Joaquin River

The daily San Joaquin River flows were used to determine the operation of the South Delta barriers (see *Section 2.2.4*). The daily average flows provided by CALSIM II's DOM were calculated by distributing the CALSIM II monthly average flows to a daily pattern based on historical observations.

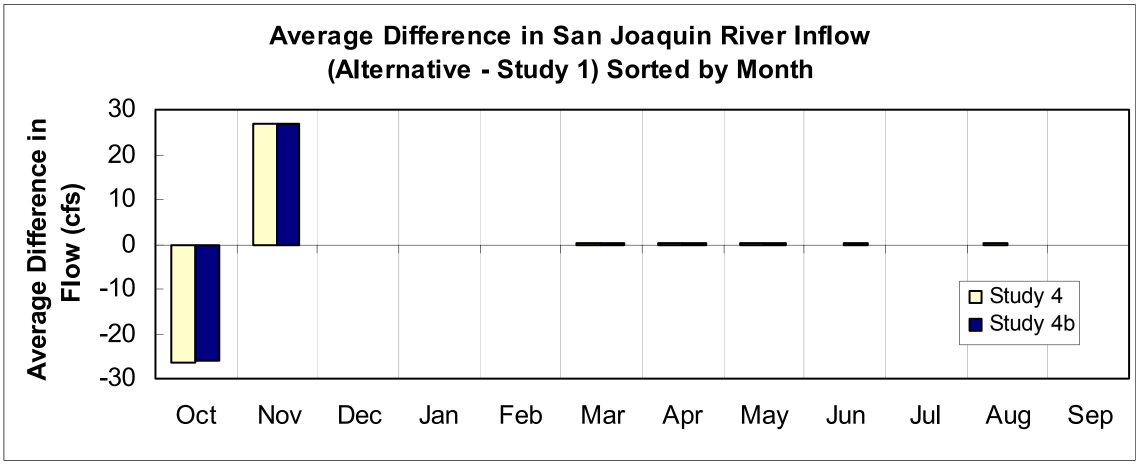

Figure 2.2.4: Difference in San Joaquin River Flows (Alternative – Study 1) Stored By Month.

The daily average flows on the San Joaquin (Figure 2.2.5) are seasonally varied over the course of the 16-year study. As shown in Figure 2.2.6, the changes in the San Joaquin flows by either alternative (study 4 or study 4b) from the base case flows are relatively insignificant. The only major change, a 400 cfs change, occurred in the Fall of 1982, and was consistent between both studies.

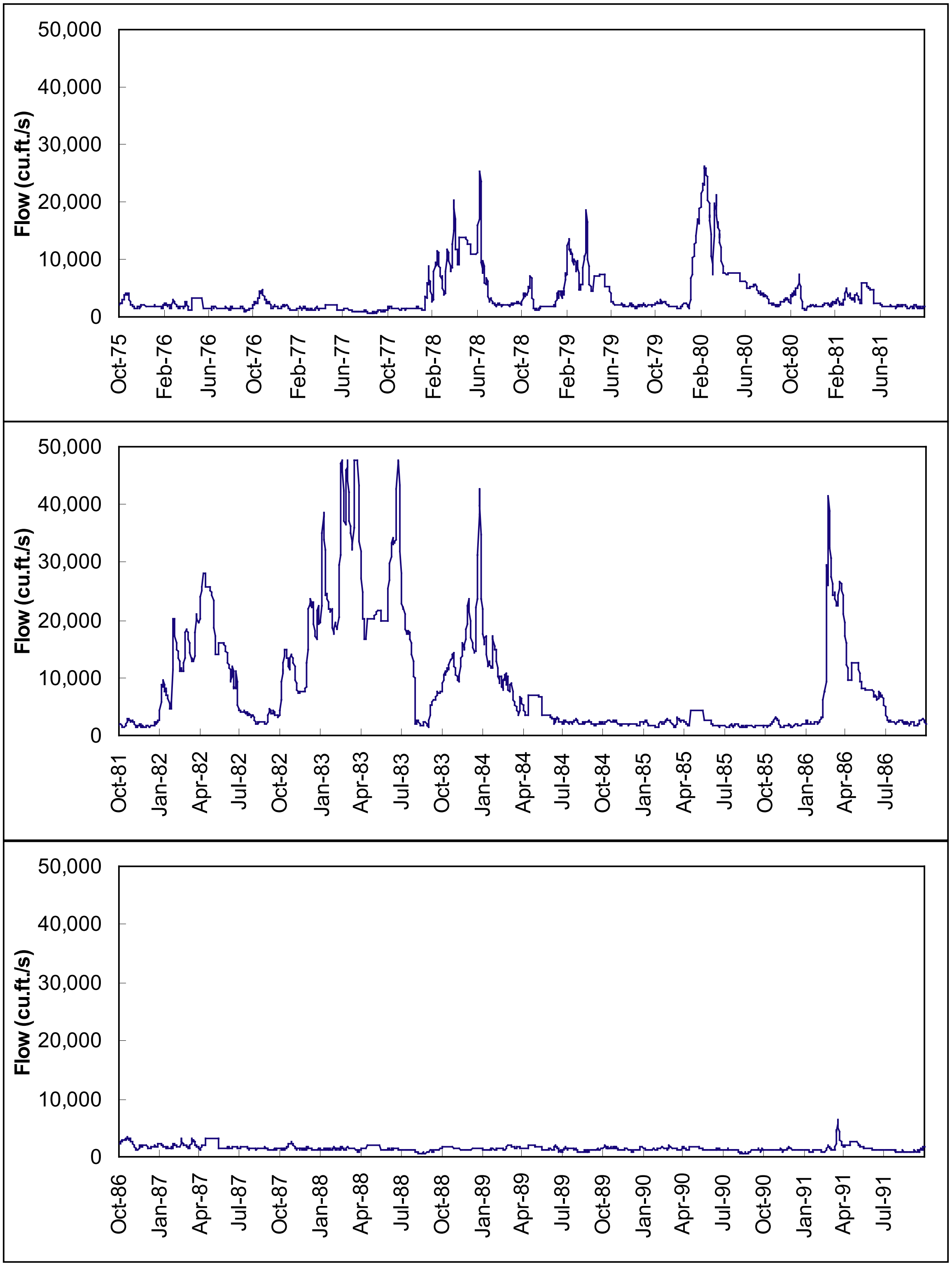

Figure 2.2.5: Daily Average Flow on the San Joaquin River for Study 1 (Base).

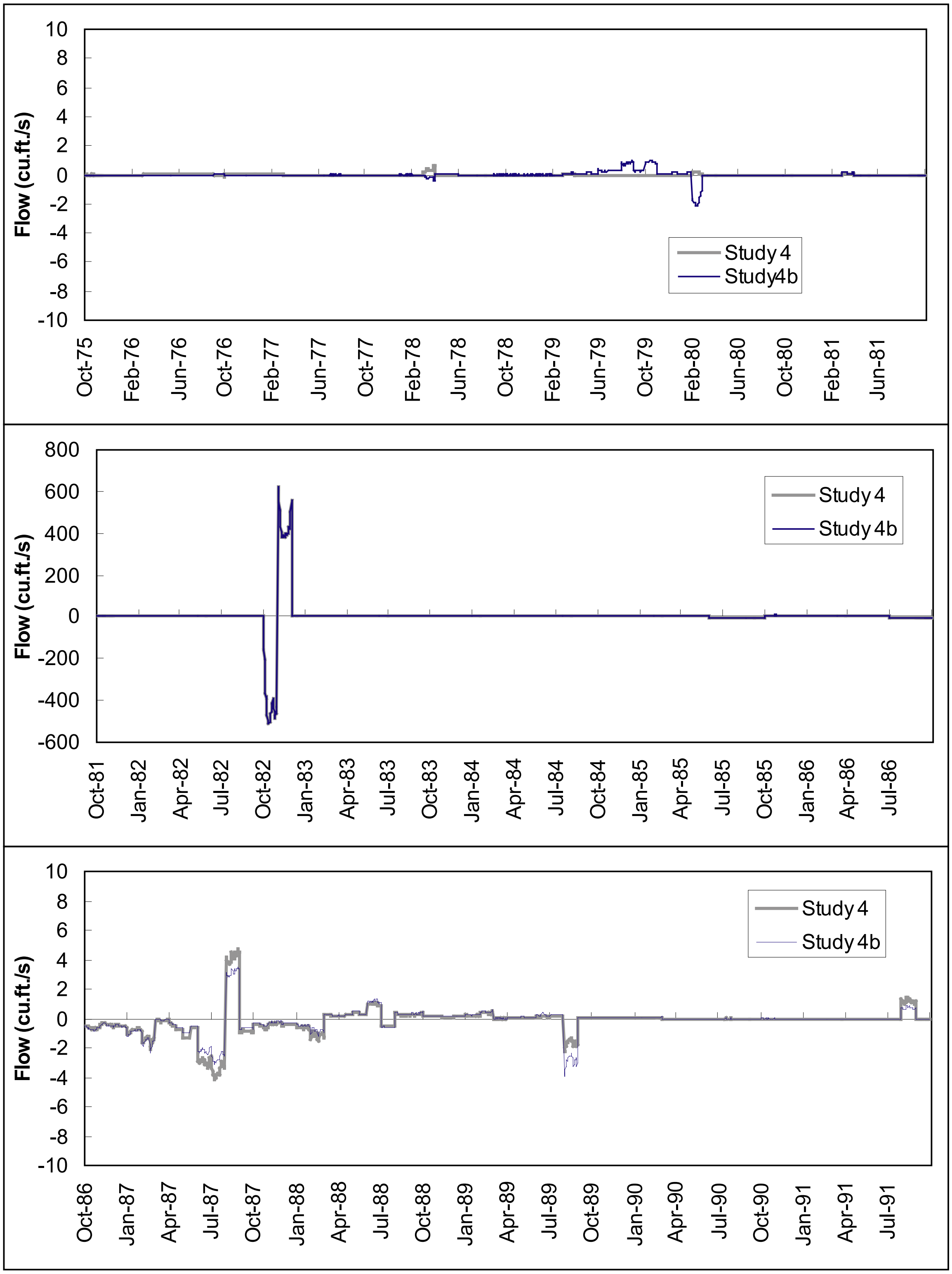

Figure 2.2.6: Change in Daily Average Flow on the San Joaquin River due to Study 4 and Study 4b.

2.2.2 Combined Exports

In addition to diversions and releases from the IDS islands (see *Section 2.4.2*), changes in the amount and timing of both the SWP and CVP exports have a significant impact on the flow patterns in the Delta. A net increase in SWP and CVP exports was expected, since the primary objective of the project was to increase SWP and CVP project storage. As shown below in Figure 2.2.7, the most significant increases in the exports occurred in July and August.

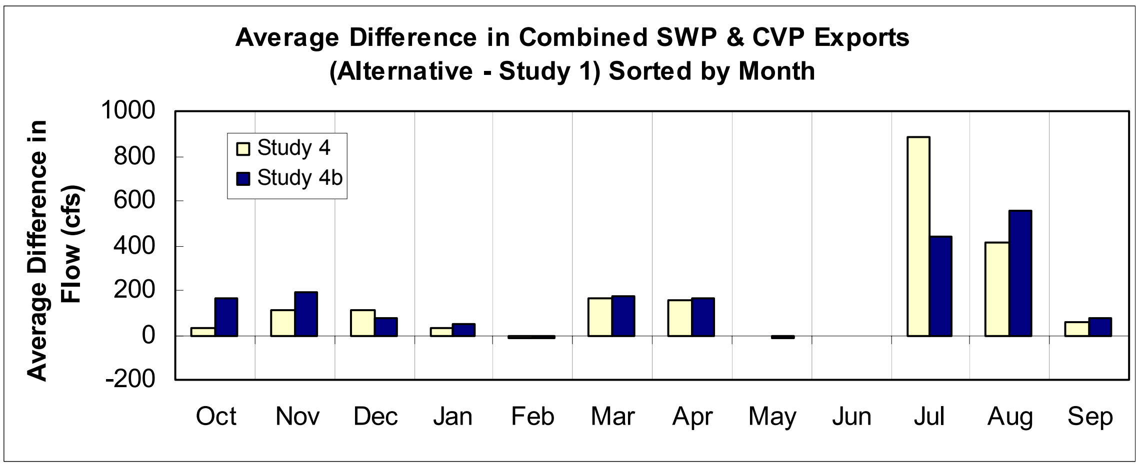

Figure 2.2.7: Difference in Combined SWP and CVP Exports (Alternative – Study 1) Stored By Month.

The daily averaged combined SWP and CVP exports for study 1 during the entire 16-year simulation are shown in Figure 2.2.8. The time series of the change in the combined SWP and CVP exports due to the operation of the project in both alternatives is shown in Figure 2.2.9.

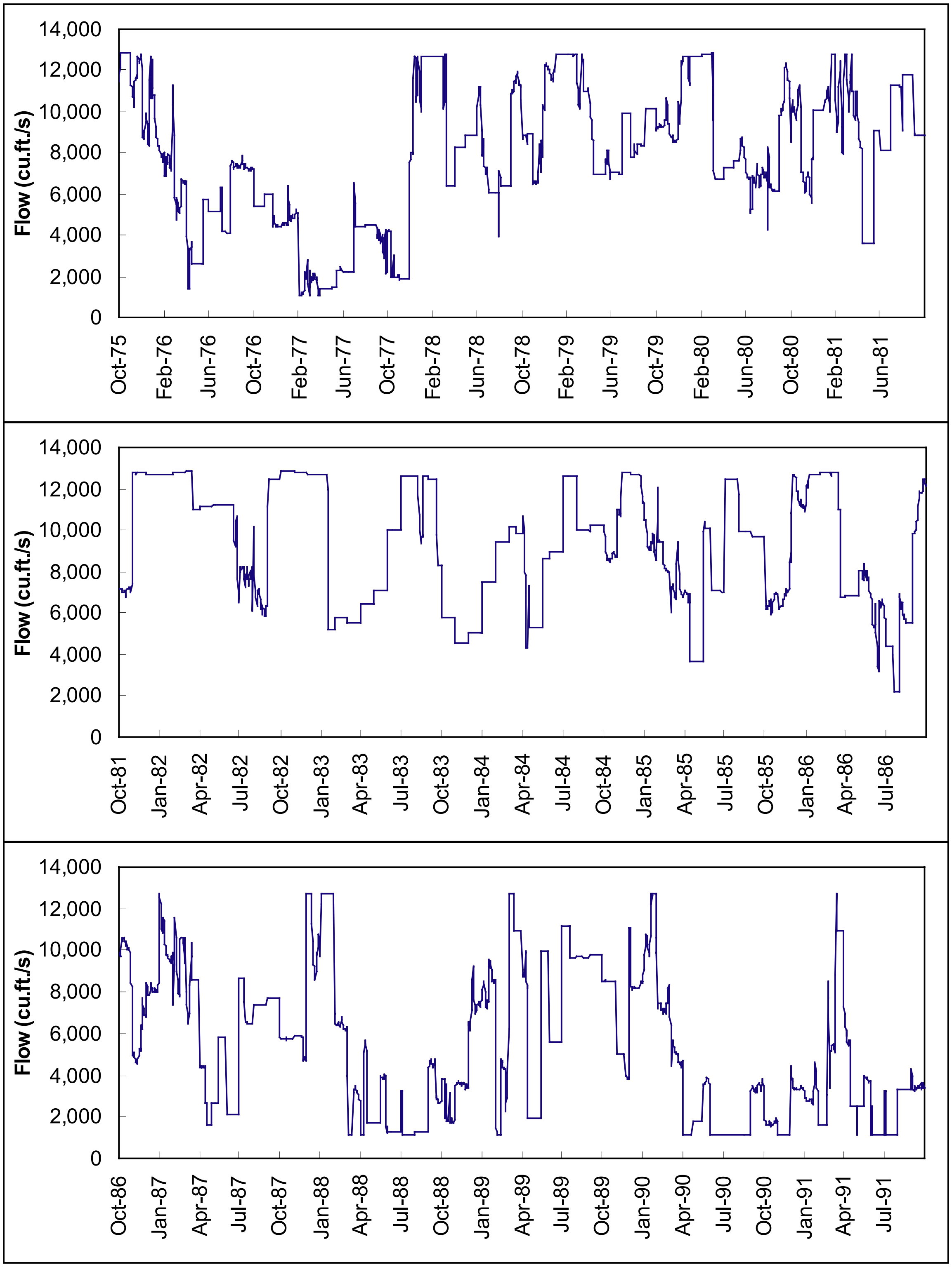

Figure 2.2.8: Daily Average Combined SWP and CVP Exports for Study 1 (Base).

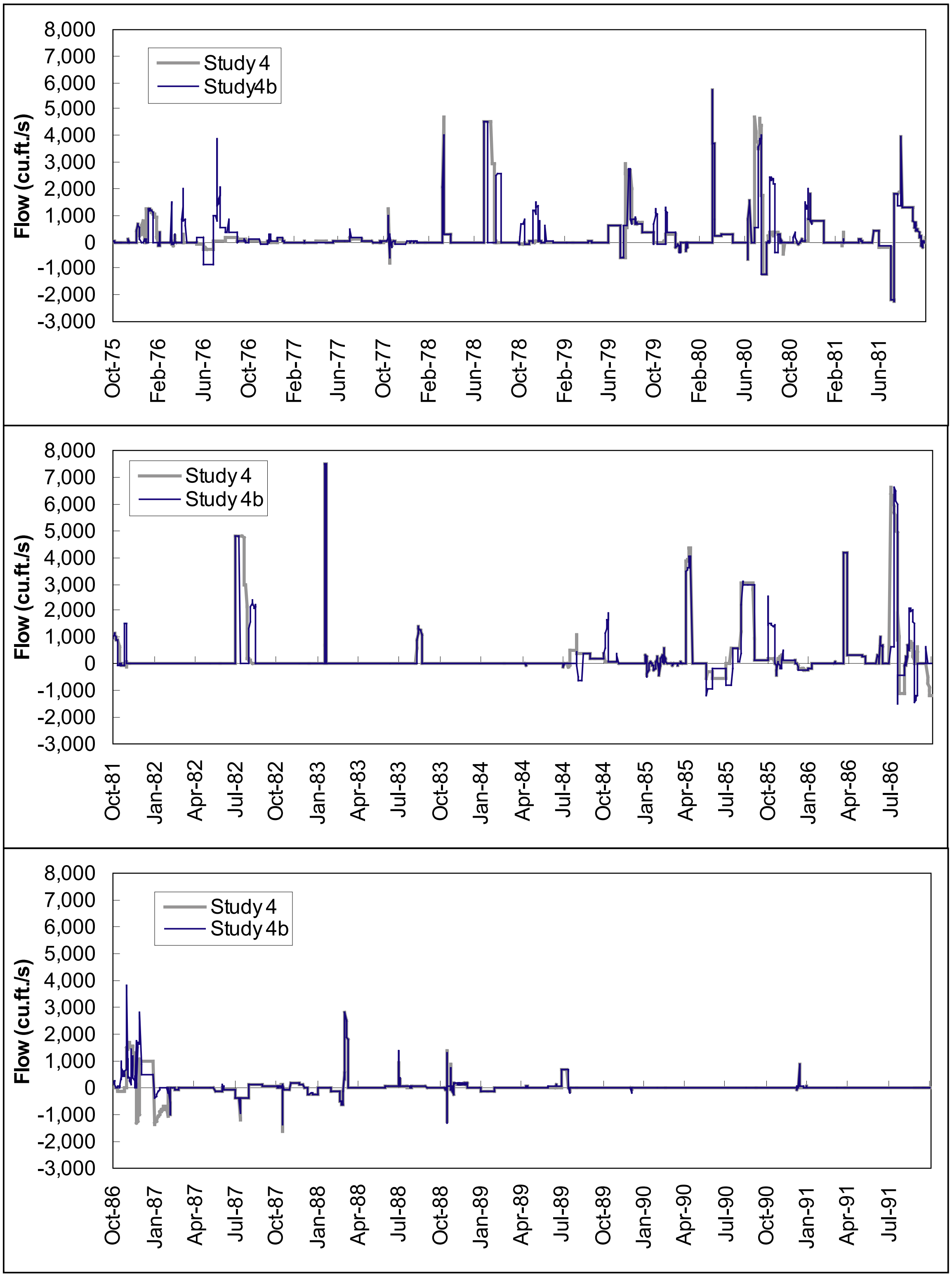

Figure 2.2.9: Change in Daily Average Combined SWP and CVP Exports due to Study 4 and Study 4b.

2.2.3 Contra Costa Water District Diversions / Exports

CALSIM II calculates CCWD's combined Rock Slough and Los Vaqueros Reservoir diversions and exports at a single point. Though DSM2's grid would make it possible to simulate the two urban intakes independently, it would be necessary to develop a series of rules to emulate the CCWD operation. DSM2 assumed that all of the CALSIM II CCWD diversions were from Rock Slough.

The significance of this assumption has not been tested, but the location of the CCWD diversions and exports may also be sensitive to the type of water quality constituent being simulated. For example, by assuming all CCWD diversions take place at Rock Slough, water quality results at Rock Slough are more likely to include a higher percentage of ocean water, while water in the Old River is more likely to include a lower percentage of ocean water. Since ocean water is a significant source of chlorides, this assumption could result in higher Rock Slough chloride concentrations and lower Los Vaqueros Reservoir intake (and possibly SWP and CVP) chloride concentrations.

2.2.4 Gates and Barriers

The operation of the Delta Cross Channel was taken directly from CALSIM II. As described by Easton (2003), the DCC can be opened only on specific days per month, as specified in input to CALSIM II. However, the DCC will be closed on any day when:

- Sacramento River Delta inflow exceeds 25,000 cfs,
- Mokelumne River Delta inflow exceeds 8,700 cfs, or
- The Rio Vista minimum instream flow requirement constrains Delta operations and the flow in Georgiana Slough if the DCC is closed will be sufficient to meet the necessary Delta exports.

Though the monthly average of percentage of time the DCC was opened is nearly the same for all the scenarios (e.g., Table 2.2.1), the daily operation of the DCC was much more varied between different scenarios.

Table 2.2.1: Monthly Average of Percentage of Time DCC Open.

Scenario	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*
Study 1	86%	54%	38%	25%	0%	0%	0%	0%	81%	99%	100%	94%
Study 4	86%	56%	38%	25%	0%	0%	0%	0%	81%	99%	100%	94%
Study 4b	86%	55%	38%	25%	0%	0%	0%	0%	81%	99%	100%	94%

The four South Delta barriers, Middle River, Old River, Grant Line Canal (west), and Head of Old River at the San Joaquin River, were modeled as permanent barriers. The purpose of the first three barriers is to improve the water levels in the South Delta. The Head of Old River at the San Joaquin River barrier is designed to prevent fish from swimming down the Old River and ending up at the SWP and CVP pumps.

All four barriers were treated as gated weirs. Flow could pass in either direction of the barriers when the gates in the barriers were not operating. When the gates were operating, the barriers restricted flow downstream through the barrier.

The locations of all four barriers are shown below (Figure 2.2.10). The operations for all four barriers are listed in Tables 2.2.2, 2.2.3, and 2.2.4. The same operations were used in the base and alternative simulations. Although the Old River and Middle River barriers used the same schedule of operations, the physical configuration of the two barriers was different. This schedule of operations was based on a CALSIM II D1641 monthly study.

San Joaquin River flows were used to determine when the gates in the barriers should not be operated. When the flow in San Joaquin River exceeded 8,600 cfs (such as it did in 1982 and 1983), the Head of Old River at San Joaquin River fish barrier was not operated. Similarly, when the flow in the San Joaquin River exceeded 20,000 cfs, the remaining three barriers were not operated.[1]

[1] Although this study was based on daily average CALSIM II flows, the schedules of barrier operations were based on SJR flows from an older D1641 monthly CALSIM II study. Though the daily average CALSIM II flows were based on monthly CALSIM II results, in June 1978, some of the daily average flows exceeded the SJR flow removal criteria listed above.

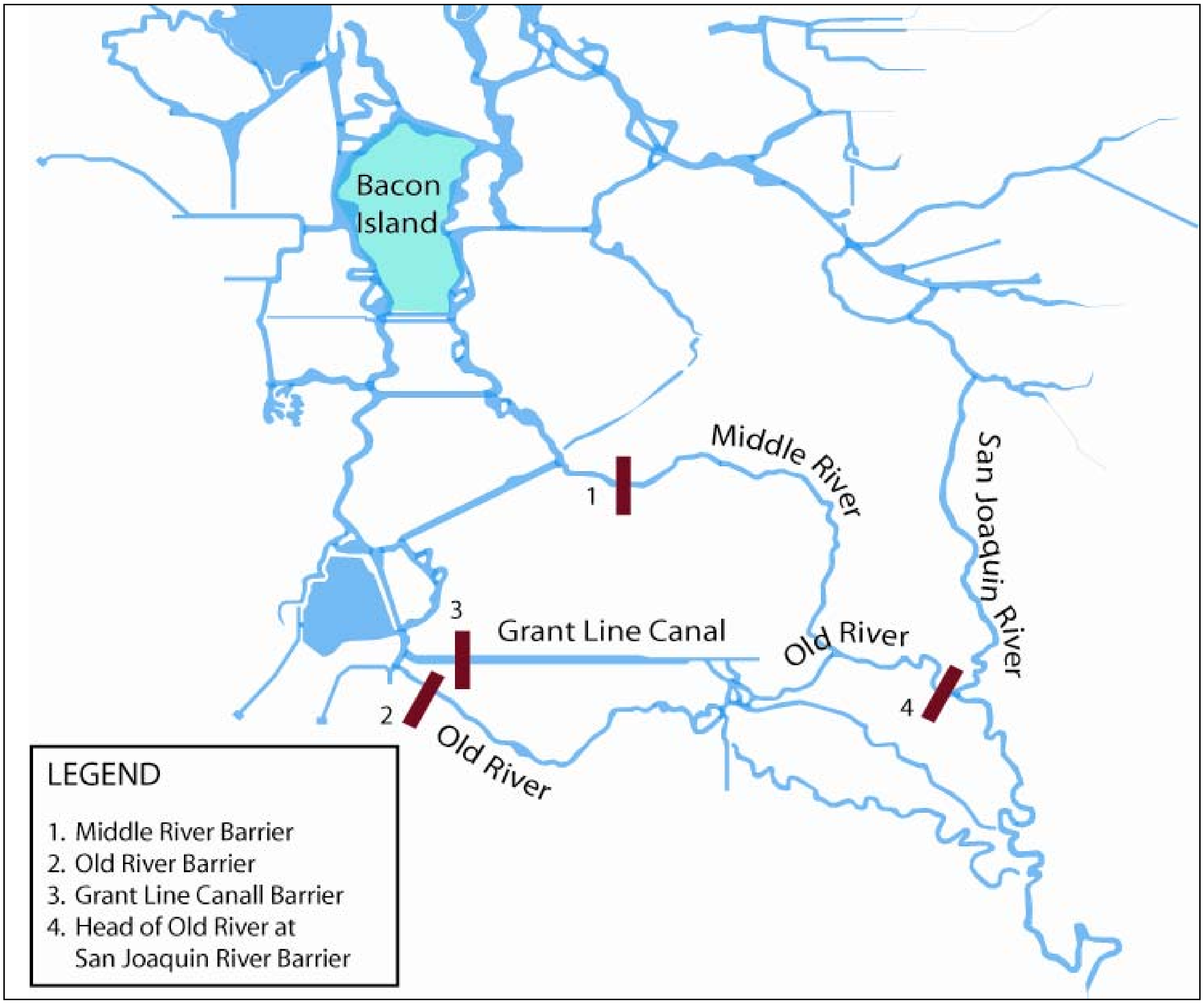

Figure 2.2.10: South Delta Permanent Barrier Locations.

Table 2.2.2: Old River and Middle River Barrier Operation.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1975												
1976												
1977												
1978												
1979												
1980												
1981												
1982												
1983												
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991												

Legend

Gates are not operating, i.e. open

Gates are operating, i.e. closed (restricts downstream flow)

Table 2.2.3: Grant Line Canal Barrier Operation.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1975												
1976												
1977												
1978												
1979												
1980												
1981												
1982												
1983												
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991												

Legend

Gates are not operating, i.e. open

Gates are operating, i.e. tidal operations (restricts downstream flow)

Table 2.2.4: Head Old River at San Joaquin River Barrier Operation.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1975												
1976												
1977												
1978												
1979												
1980												
1981												
1982												
1983												
1984												
1985												
1986												
1987												
1988												
1989												
1990												
1991												

Legend

Barrier not installed

Barrier installed (restricts flow downstream when stage < 11 ft)

2.2.5 Delta Island Consumptive Use

Though originally used to calculate Delta wide consumptive use for the original Delta Simulation Model (DWRDSM) as described by Mahadevan (1995), the DICU model has been modified to calculate the historical consumptive use in the Delta for DSM2. In order to remain consistent with the level of development used in the CALSIM simulations, a 2020-Level of Development was used to adjust the historical Delta Island consumptive use using the department's ADICU model. The adjusted consumptive use was then applied to 257 locations (model nodes) in the Delta to represent agricultural diversions and returns to and from Delta islands and the seepage from Delta channels to the islands.

The scope of this study is not to account for the impact of the operation of the project islands on the entire Delta, but rather to focus on quantifying the water quality impacts at the four major urban intakes. Thus, the same consumptive use patterns were used in both the base (study 1) and alternative (study 4 and 4b) simulations. Even though the land use associated with the two project islands would be different for the alternatives based on the real operation of the project, it was decided to not rerun the DICU and ADICU models to account for the changes in land use. Previous DSM2 studies (Mierzwa, 2001) have shown that the change in base case simulated DOC at the State Water Project (SWP) and Rock Slough (RS) intakes due to removing the return flows (and hence the water quality associated with those follows) from Bacon Island and Webb Tract is small.

2.3 Delta Water Quality

Water quality inputs, EC and DOC, were applied in DSM2-QUAL to the flows generated in DSM2-HYDRO at the river and ocean Delta boundaries and at interior Delta locations. With the exception of EC at Martinez, the water quality concentrations for both EC and DOC at all of the flow inputs into the Delta were based on standard monthly varying DSM2 planning studies concentrations (i.e. the concentrations themselves did not change between studies). However, the relative amount of each constituent brought into the Delta is variable between studies. The amount at each boundary input is the product of the concentration assumed for that boundary and the volume of water that enters at the boundary.

EC and DOC were simulated as a conservative constituent while in the Delta channels. DSM2 has been calibrated and validated for EC and validated for DOC (insert reference to EC and DOC calibration and validations). However, DOC was treated as a non-conservative constituent inside the project islands (see *Section 2.4.4*). The mixing of Delta water with island water is discussed in *Sections 2.4.3 and 2.4.4*.

2.3.1 EC

Martinez EC was generated using Net Delta Outflow from the CALSIM II daily results and an updated G-model (Ateljevich, 2001). By incorporating tidal information into the process of estimating EC at Martinez, data was generated for a 15-minute time step. Since Sacramento inflow is an important component to Net Delta Outflow, the 15-minute Martinez EC was different in all of the simulations.

Monthly CALSIM II Vernalis EC was smoothed to a 1-hour time step using a mass conservative tension spline.[2] The hourly EC at Vernalis was virtually identically for all of the simulations.

Lack of adequate EC – flow relationships made it necessary to assume fixed concentrations to assign to the flows at the other major inflow boundaries to the Delta (see Table 2.3.1). These values are the standard values used to represent the quality associated with these inflow boundaries. The concentrations were used in study 1 and study 4b (EC was not simulated in study 4).

Table 2.3.1: EC at Delta Inflow Boundaries.

Boundary Inflow	EC (umhos/cm)
Sacramento River	160
Yolo Bypass	175
Eastside Streams (Mokelumne and Cosumnes Rivers)	150
City of Stockton Waste Water Treatment Plant Releases	0

[2] This mass conservative tension spline is a specific type of spline that preserves the monthly average value when creating hourly values.

The monthly varying EC concentrations assigned to the agricultural return flows are based on field observations that have been prepared for use in DSM2 by the Delta Island Consumptive Use (DICU) model (DWR, 1995). This report divided EC return concentrations into three sub regions: north, west, and southwest, based on Bulletin 123 and Municipal Water Quality Investigations (MWQI) data. The same monthly varying time series was used each year for each sub region (i.e. every October for the north sub region assigned the same concentration to agricultural return flows in the north sub region). However, as discussed in Section 2.2.5, the agricultural return flows changed from year to year, thus an individual island's EC contribution to the Delta would change at the product of its return flow and repeating monthly concentration. The same concentrations were used in study 1 and study 4b.

2.3.2 DOC

DOC from the ocean boundary at Martinez and Stockton Waste Water Treatment Plant releases were considered negligible (i.e. 0 mg/L). The standard monthly varying DSM2 16-year planning study DOC concentrations applied at the remaining DSM2 flow input boundaries were generated based on historical DOC – flow relationships (Suits, 2002). The DOC concentrations associated with agricultural return flows are based on DICU model results (Jung, 2000). The Delta was divided into three sub regions based on observed DOC return quality concentrations: low-, mid-, and high-range DOC. These sub regions are different than those associated with EC.

2.4 Project Islands

The principle difference between study 1 (no action base) and the two alternatives (study 4 and study 4b) was the addition and operation of the IDS project island reservoirs: Bacon Island and Webb Tract. The location of the two project islands is shown in Figure 2.4.1. In the two DSM2 alternative simulations, the project islands were modeled as isolated reservoirs. The representation of the project islands in DSM2 is described below in *Section 2.4.1*.

In addition to isolating the reservoirs from the Delta channels, several additional processes unique to operating the IDS project island as short-term reservoirs were addressed. The processes related to hydrodynamics include: diversion and release schedules (at two integrated facilities per island), evaporation losses, and seepage returns (see Figure 2.4.2). The island processes related to hydrodynamics are described in *Section 2.4.2*.

Water quality in each project island is related to the concentration of the inflows and the concentration already in the island. EC in the project islands is treated as a conservative constituent. A complete description of mixing conservative constituents is discussed in *Section 2.4.3*. As shown in Figure 2.4.2, several important organic carbon sources, representing the interaction of the island water with the organic carbon rich peat soils and the bioproductivity of carbon from aquatic plants and algae, provide additional organic carbon mass to the project islands. A detailed description of the method used to account for this non-conservative treatment of DOC is discussed in *Section 2.4.4*.

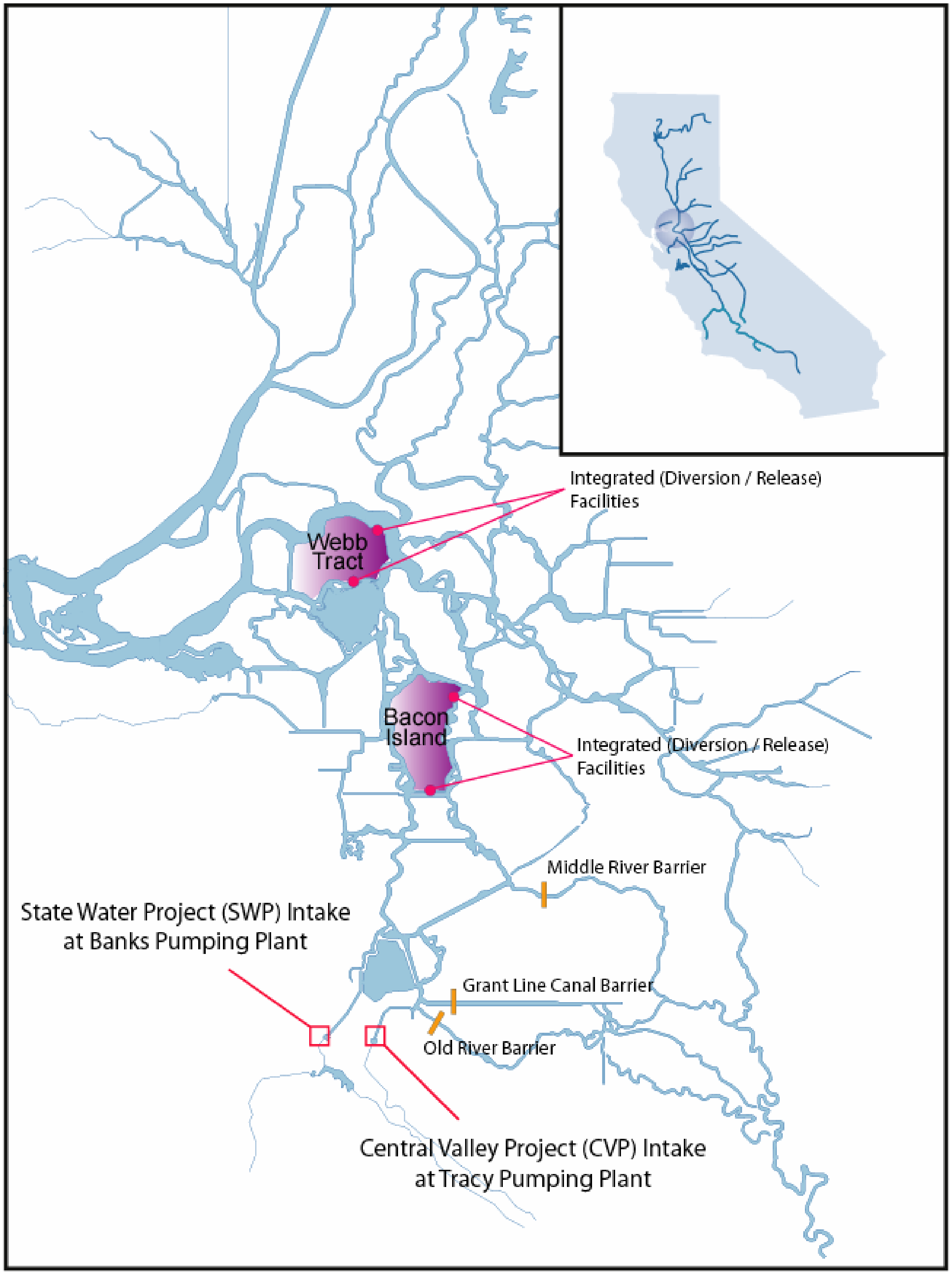

Figure 2.4.1: Location of Project Islands.

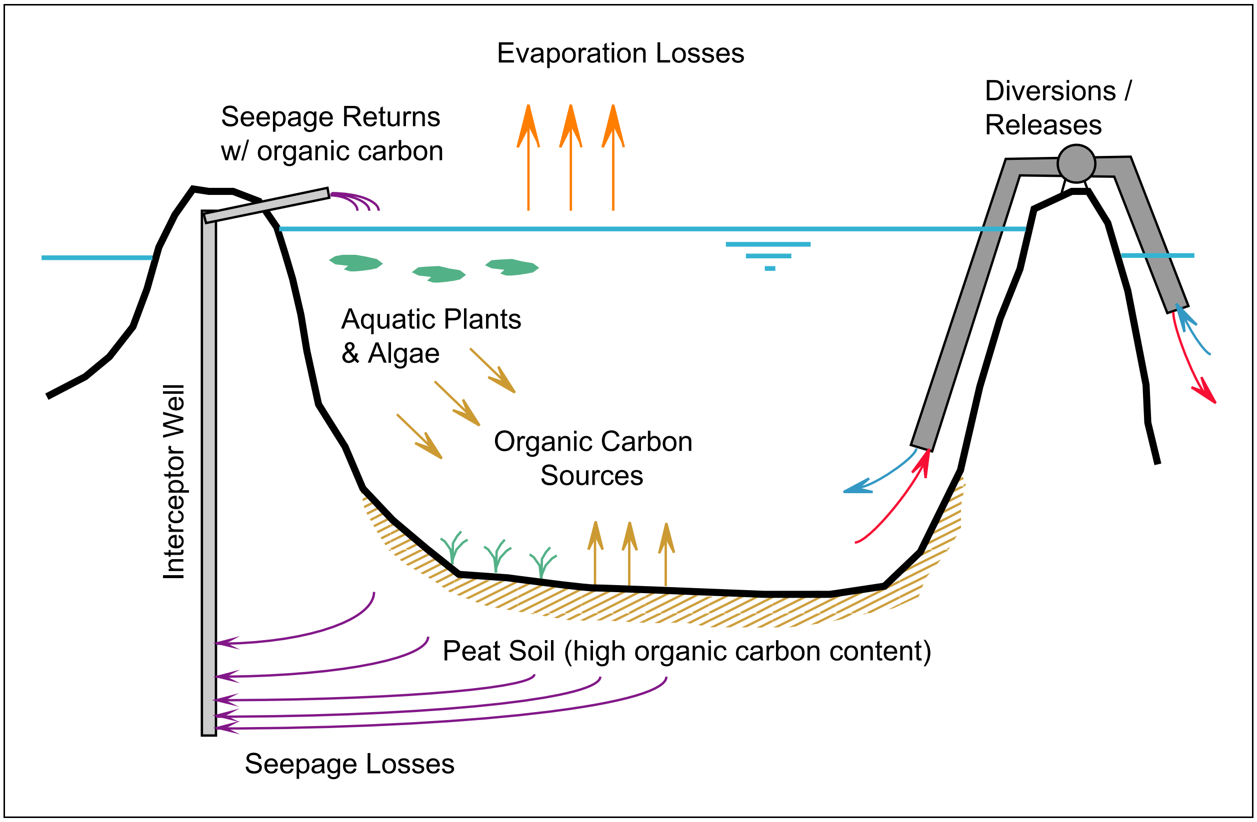

Figure 2.4.2: Project Island Processes Simulated in DSM2.

2.4.1 DSM2 Physical Representation of the Project Islands

DSM2 treats reservoirs as tanks with constant surface areas and variable depths, thus elevation (stage) in the reservoirs is a linear function associated with net flows into (or out of) the reservoirs. The DSM2 surface area for each reservoir was fixed such that when at a depth of 20 ft that each island's storage capacity would approximate its design storage capacity. The configuration of the project islands as modeled by DSM2 is shown in Table 2.4.1.

Table 2.4.1: DSM2 Project Island Configuration.

Island	Design Storage Capacity (TAF)	DSM2 Surface Area (acres)	Northern Integrated Facility DSM2 Node	Southern Integrated Facility DSM2 Node
Bacon Island	120	5,450	128	213
Webb Tract	118	5,370	40	103

In order to prevent DSM2 from drying up (DSM2 does not support wetting and drying, thus some amount of water must always be kept on every channel or reservoir in the model), a dead pool of 0.1 ft was added. The initial depth of the active storage pool at the start of each DSM2 simulation was determined by relating the CALSIM storage to the following DSM2 storage-depth relationship:

$$Stage_{DSM2} = \frac{Storage_{CALSIM} \times 1000}{A_{DSM2}} + BottomElev_{DSM2} + Stage_{DeadPool} \qquad \text{Eqn. 4.1}$$

where,

A_{DSM2}	= DSM2 Surface Area (acres),
$BottomElev_{DSM2}$	= DSM2 Reservoir Bottom Elev (ft),
$Stage_{DSM2}$	= Initial Stage in DSM2 (ft),
StageDeadPool	= Depth of the DSM2 Dead Pool (ft), and
$Storage_{CALSIM}$	= Storage in CALSIM at start of DSM2 simulation (taf).

Two integrated (diversion and release) facilities were used on each island to fill and empty the island reservoirs. The location of the each integrated facility in DSM2 corresponds with the approximate field location (see Figure 2.4.3 and Table 2.4.1). A description of the modeled operation of the facilities for both islands is explained in *Section 2.4.2.1*.

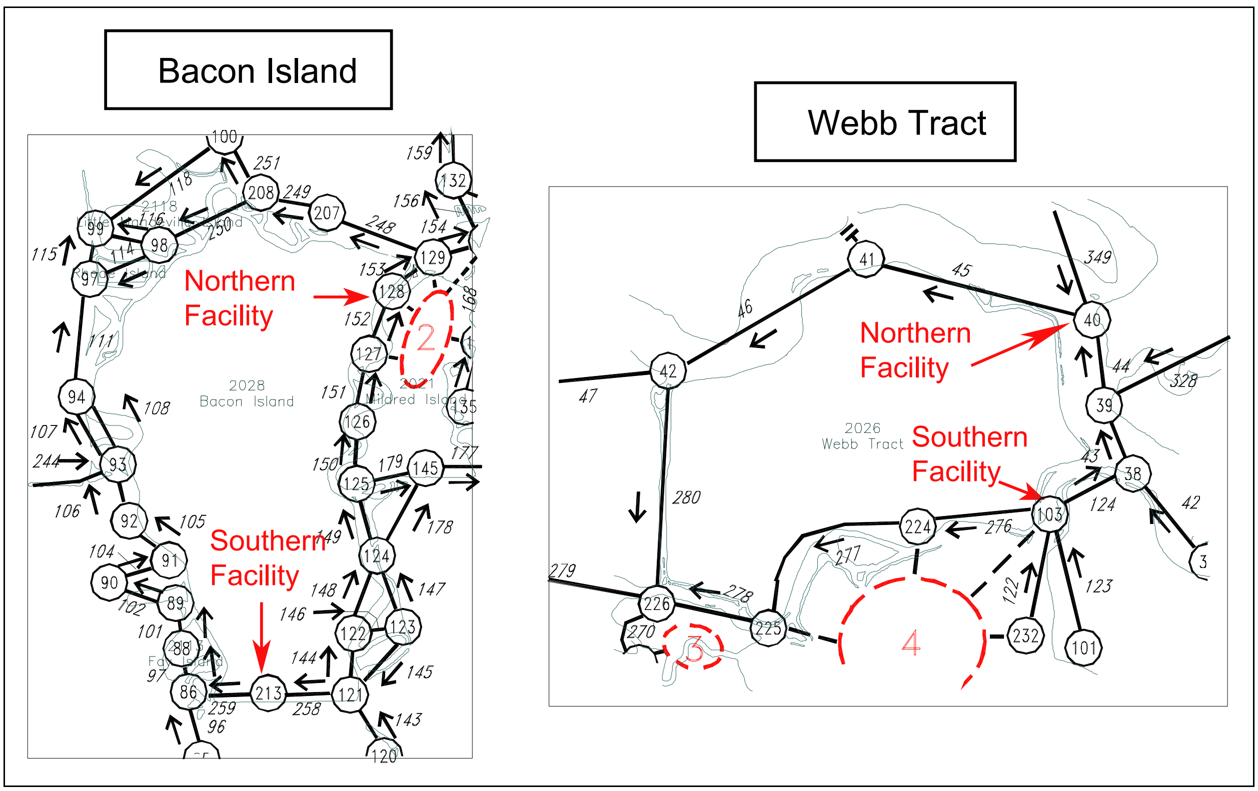

Figure 2.4.3: DSM2 Grid Surrounding Bacon Island and Webb Tract.

2.4.2 Project Island Hydrodynamics

For study 4 and study 4b, CALSIM II determined the daily diversions to and releases from the project islands, in addition to optimizing the exports at both the Banks (SWP) and Tracy (CVP) Pumping Plants. Depending upon water quality and project constraints, project diversions and releases were used to improve water quality of the island reservoirs themselves or to meet increases SWP and CVP project demands. Diversions to and releases from the project islands to the surrounding channels were controlled in DSM2-HYDRO by "object-to-object" transfers when simulating EC and DOC (study 4b). The other two hydrodynamic processes unique to the project islands: evaporation and seepage were included in the simulation of the reservoirs in study 4b.

For the fingerprinting simulation (study 4), the project islands were not directly modeled. The diversions and releases were treated as additional sinks and sources, not unlike the way DSM2 simulates the urban exports and river inflows to the Delta. Since the project islands were not directly modeled, there was no need to include estimates of evaporation or seepage when simulating the hydrodynamics for the fingerprinting runs. The flow rates assigned to the diversions and exports were the same as those used in study 4b, thus the quantity of water in the Delta Channels remain unchanged.

There was no direct physical connection between the project islands and neighboring channels. Instead, water was pumped via two integrated facilities for each island (see *Section 2.4.2.1*). Diversions onto an island were assumed to be uniformly mixed with the water already present on the island. The concentration of EC or DOC released from an island was assumed to be the same concentration of the island, thus releases had no immediate impact on the island's EC or DOC concentration. However, releases from the islands had immediate and at times significant impacts on the EC and DOC concentrations of neighboring channels. In the case of a diversion scheduled soon after or concurrent to a release (which is typical in a circulation operation), the newly mixed water from the release may move to the diversion point and be returned to the island.

2.4.2.1 Integrated Facilities: Diversions and Releases

Each island used two different integrated facilities to divert and release water (see Figures 2.4.1, 2.4.2, and 2.4.3). The northern Bacon Island facility is located on the Middle River near Mildred Island. The southern Bacon Island facility is located in the middle of Santa Fe Cut, nearly equidistant between the Middle and Old Rivers. The northern Webb Tract facility is located on the San Joaquin River near the head of the North Fork of the Mokelumne River. The southern Webb Tract facility is located near the junction of the Old and False Rivers. The southern Webb Tract facility is also near the northeastern corner of Frank's Tract.

Diversions to and releases from the island reservoirs were taken directly from the CALSIM II, thus the storage simulated in DSM2 is identical to the storage used in CALSIM II. Although CALSIM II combined the north and south facilities for each island, the following basic operation rules were used by DSM2 to divide the CALSIM II derived flows between the two facilities:

Diversions	Releases

If $Div_{CALSIM} > 2250$ cfs Then
$Div_{SouthDSM2} = 2250$ cfs
$Div_{NorthDSM2} = Div_{SouthDSM2} - Div_{CALSIM}$
Else
$Div_{SouthDSM2} = Div_{CALSIM}$
	If $Rel_{CALSIM} > 2250$ cfs Then
	$Rel_{NorthDSM2} = 2250$ cfs
	$Rel_{SouthDSM2} = Rel_{NorthDSM2} - Rel_{CALSIM}$
	Else
	$Rel_{NorthDSM2} = Rel_{CALSIM}$

where,

Div_{CALSIM} = CALSIM Total Island Diversion (cfs),
$Div_{SouthDSM2}$ = DSM2 Diversion at Island's Southern Facility (cfs),
$Div_{NorthDSM2}$ = DSM2 Diversion at Island's Northern Facility (cfs),
Rel_{CALSIM} = CALSIM Total Island Release (cfs),
$Rel_{SouthDSM2}$ = DSM2 Release at Island's Southern Facility (cfs), and
$Rel_{NorthDSM2}$ = DSM2 Release at Island's Northern Facility (cfs).

The above project island integrated facility operation rules can be generalized to say that the majority of the project diversions will be taken from each island's southern facility, while the majority of the project releases will occur at each island's northern facility. Diversions and releases to and from the project islands for each island as a whole and the north and south integrated facilities on each island are summarized in Tables 2.4.2 and 2.4.3 for both study 4 and study 4b. The percent of time that water was diverted to or released from the project islands was calculated as the number of days that there was any positive diversion or release over the course of the 16-year DSM2 simulation. The average diversions and releases were calculated only when there was a positive diversion or release respectively (i.e. this value is not for the entire 16-year simulation, but represents the average diversion or release). The average diversions include small "topping-off" diversions made throughout the year to account for evaporation losses, thus the average of diversions greater than 100 cfs is also presented in Table 2.4.2.

Table 2.4.2: Summary of DSM2 Project Island Diversions.

Island	Study	Facility	% Time of Diversions		Ave. Diversion (cfs)		Max. Div. (cfs)
			Div. > 0 cfs	Div. > 100 cfs	Div. > 0 cfs	Div. > 100 cfs	
Bacon Island	Study 4	Total	66.2%	4.7%	165	2,247	4,500
		North	1.8%	1.7%	1,511	1,525	2,250
		South	66.2%	4.7%	125	1,677	2,250
	Study 4b	Total	80.7%	53.6%	324	475	4,500
		North	1.7%	1.7%	1,316	1,328	2,250
		South	80.7%	53.6%	297	433	2,250
Webb Tract	Study 4	Total	77.7%	3.3%	107	2,365	4,500
		North	1.3%	1.3%	1,704	1,725	2,250
		South	77.7%	3.3%	77	1,676	2,250
	Study 4b	Total	89.4%	55.9%	259	408	4,500
		North	1.8	1.6%	1,348	1,457	2,250
		South	89.4%	55.9%	232	365	2,250

Table 2.4.3: Summary of DSM2 Project Island Releases.

Island	Study	Facility	% Time of Releases	Ave. Release (Releases > 0 cfs) (cfs)	Max. Release (cfs)
Bacon Island	Study 4	Total	7.2%	1,467	3,000
		North	7.2%	1,288	2,250
		South	2.3%	571	750
	Study 4b	Total	55.6%	460	3,000
		North	55.6%	444	2,250
		South	1.9%	540	750
Webb Tract	Study 4	Total	3.5%	2,117	3,000
		North	3.5%	1,716	2,250
		South	2.1%	676	750
	Study 4b	Total	55.6%	406	3,000
		North	55.6%	386	2,250
		South	1.7%	603	750

The maximum diversion or release at any of the facilities was limited to 2,250 cfs. The maximum diversion for the islands was 4,500 cfs, while the maximum release was limited to 3,000 cfs. The difference in the percent of time that water is diverted in each island's southern facility versus the amount of time that water is diverted in the northern facility is due to the diversion of small amounts of water in order to account for evaporation losses. The average diversions, including these "topping-off" operations and without these operations (i.e. diversions greater than 100 cfs), are shown in Table 2.4.2. The average diversions excluding the topping-off operations are more representative of the flows that will have a significant impact on the water quality in the island reservoirs.

2.4.2.2 Operation Strategies: Circulation

One of the primary differences between study 4 and study 4b is the use of a circulation operation in study 4b in order to improve the water quality in the project islands.[3] Circulation operations take advantage of the fact that both islands have two integrated facilities, by diverting water through on facility while simultaneously releasing water through the other facility. The net difference in flow rates will determine if water is being stored or released from the project islands. For this particular circulation simulation, CALSIM limited the circulation to 500 cfs. Like the standard release operations, releases made under a circulation operation still are subject to all Delta water quality standards. Figure 2.4.4 shows examples of the relative flow rates for the north and south facilities for diversion only, release only, and circulation operations.

[3] The other primary difference is the addition of DOC constraints to study 4b. These constraints were developed using fingerprinting information from study 4 even though it did not include a circulation operation.

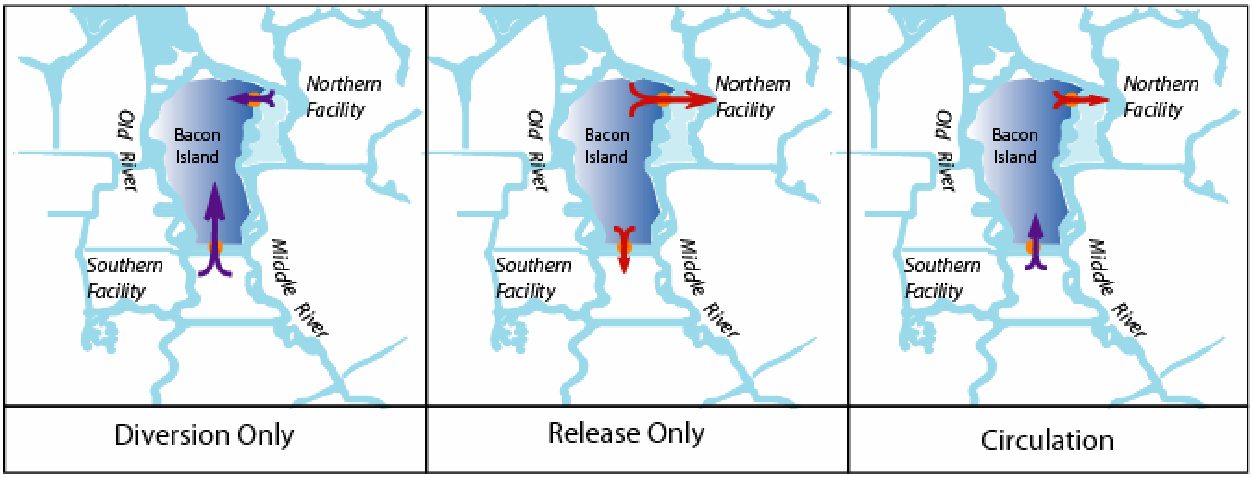

Figure 2.4.4: Examples of Typical Diversion Only, Release Only, and Circulation Operations.

2.4.2.3 Evaporation Losses

In addition to diversions and releases associated with operating the project islands, evaporation losses and surplus agricultural diversions were provided by CALSIM II. Under the current IDS proposal, both islands will retain their agricultural diversion water rights, and this water was used to make up for the evaporation losses. Since the reservoirs were simulated as sinks and sources of additional water for the fingerprinting work (study 4), evaporation losses were only included in study 4b (see Table 2.4.4). These evaporation losses were applied directly to each project island.

Table 2.4.4: Summary of CALSIM II Evaporation Losses for Study 4b.

Island	Min CALSIM II Evaporation (cfs)	Ave CALSIM II Evaporation (cfs)	Max CALSIM II Evaporation (cfs)
Bacon Island	0.8	10.5	42.8
Webb Tract	1.1	10.0	42.2

Though the evaporation losses vary from day to day, they do follow typical seasonal cycles. The minimum evaporation losses occurred in December, while the maximum evaporation losses occurred in June. This evaporation losses and the shifting of the historical diversion of additional water to make up for these losses resulted in minor fluctuations in island storage.

2.4.2.4 Seepage

Because the elevation of most Delta islands is lower than the low tide water surface in the channels that surround the islands, seepage usually occurs from the channels onto the islands. This typical seepage pattern (see Figure 2.4.5) is accounted for by the DICU Model and simulated in DSM2 for all Delta islands, including the project islands. However, when water is stored on the IDS project islands, the gradient of ground water flow between the neighboring channels and islands will at times be reversed (see Figure

2.4.5). Water from the island reservoirs would move to the channels, carrying with it organic carbon from the island peat soils.[4]

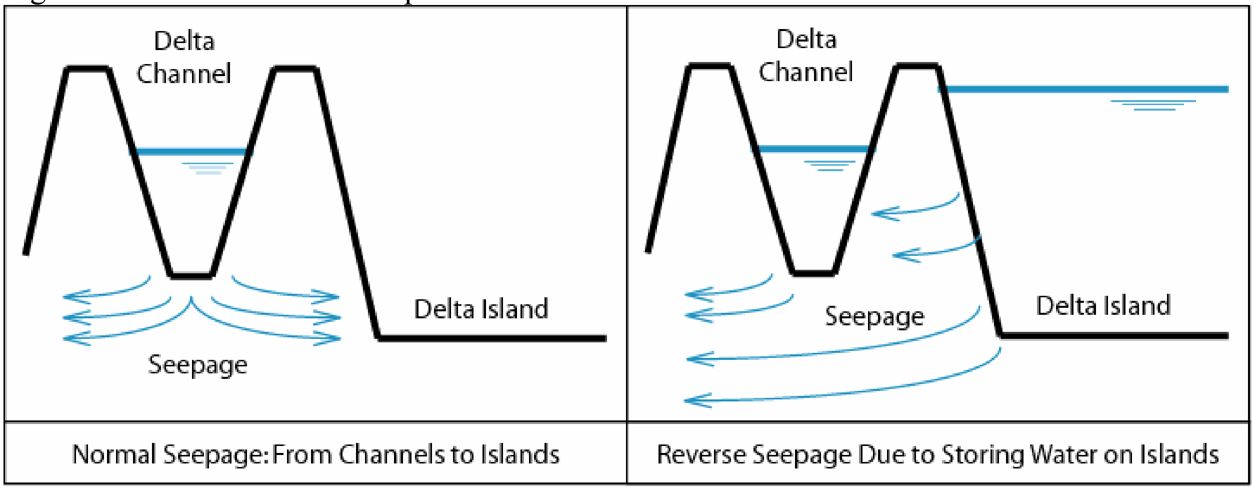

Figure 2.4.5: Comparison of Normal Seepage and Reverse Seepage Due to IDS.

To prevent this reverse seepage, the IDS project will use interceptor wells to collect water moving from the islands to the channels. After collecting the water, the wells will return the seepage flows back to the island.

Although there is no net change in storage due to seepage when using wells to return water lost due to seepage, the collected water will have a high concentration of organic carbon. In order to account for the addition of this organic carbon to the island reservoirs, seepage losses and returns were provided by DWR's Integrated Storage Investigations group for both Bacon Island and Webb Tract. The seepage flow rates used in DSM2 are summarized in Table 2.4.5. Since DSM2 treats reservoirs as buckets (i.e. the surface area is fixed and the volume is a function of stage), the seepage losses were not divided between the different wells, but instead were taken directly from the island reservoir. The return flows from the interceptor wells were added back to the reservoirs. There is no interaction of the seepage water with the neighboring channels.

Table 2.4.5: Summary of Project Island Seepage for Study 4b.

Island	Seepage Flow Rate (cfs)	% of Time w/ Seepage in 16-yrs (%)	Ave. CALSIM II Stage w/ Seepage (ft)	Max. CALSIM II Stage w/ Seepage (ft)
Bacon Island	9.8	24.9%	3.2	4.0
Webb Tract	8.3	22.1%	3.5	4.0

In the field, seepage losses will occur only at times when the stage in the island reservoirs is higher than the stage of the surrounding channels; however, it was necessary to assume a fixed water level for each island to trigger when seepage would occur. Seepage flows resulted only when the stage results from CALSIM II were greater than or equal to -1.0

[4] Since the Delta Island Consumptive use for the project islands was not changed for the alternative simulations, the normal channel to island seepage (in this case a loss to the system) was not changed. Seepage from the islands to channels is being intercepted, thus some fraction of the water that would have traveled from the Delta channels to the project islands.

ft. In situations where the project islands were partially full, this reverse seepage would not occur.[5] The percentage of time during the 16-year DSM2 planning study that there was any seepage on the islands is shown in Table 2.4.5. That average and maximum CALSIM II stage results for both islands are shown in Table 2.4.5. CALSIM II's bottom elevation for Bacon Island and Webb Tract was -16 and -18 ft, respectively.

2.4.2.5 Stage / Storage

Storage is an important variable that determines the concentration of new organic carbon mass added to the reservoirs and when seepage will occur. In study 4, diversions to the islands were treated as sinks, and releases from the islands were considered sources. As with the treatment of evaporation and seepage, project island stage and storage were only simulated in study 4b.

It was already pointed out in *DSM2 Physical Representation of the Project Islands* that although DSM2 models stage in the project islands as a linear function related to a fixed reservoir surface area and the change in storage, that the storage represented in DSM2 is the exact same as the storage represented in CALSIM II. As part of the preprocessing for DSM2, CALSIM II stage results were used to calculate when seepage from the project islands would occur.

The 16-year minimum, average, and maximum daily average storage (TAF) in each project island is shown in Table 2.4.6. The storage associated with the 10th, 25th, 50th, 75th, and 90th percentiles for each location is also shown. These percentiles were computed by ranking the 5,844 daily average storage volumes for each island in ascending order, and then associating a storage with a specified percentile. The 10th percentile represents the 584th lowest concentration, the 50th percentile represents the median concentration, and the 90th percentile represents the 5260th lowest concentration (or the 584th highest concentration).

Table 2.4.6: Summary of Project Island Storage (TAF) for Study 4b.

Island	Min	Ave	Max	Percentiles				
				10th	25th	50th	75th	90th
Bacon Island	1	45	115	1	1	32	88	115
Webb Tract	1	34	101	1	1	1	72	101

The 50th percentile storages correspond with the median (middle) value. Both Bacon Island and Webb Tract were effectively empty over 25% of the time (i.e. there was no significant storage on either island in the 25th percentile). The average storage for both islands is greater than the median (50th) storage. This suggests that when the reservoir is

[5] The alternative to using a fixed CALSIM II stage trigger would have been to run iterative DSM2-HYDRO simulations. Since the volume of storage is not affected by seepage, no seepage flows would have been included I the first HYDRO simulation. The stage results from the first HYDRO simulation would be used to develop seepage estimates based on the elevation differential between an island and its surrounding channels for a second HYDRO simulation. Using this technique, the seepage flowrates could vary with time based not only on the island stage, but upon the actual gradient of water flow. Time constraints prevented this technique from being used.

full, it tends to remain full. This conclusion is supported by the time series of daily average storage for both reservoirs (Figure 2.4.6).

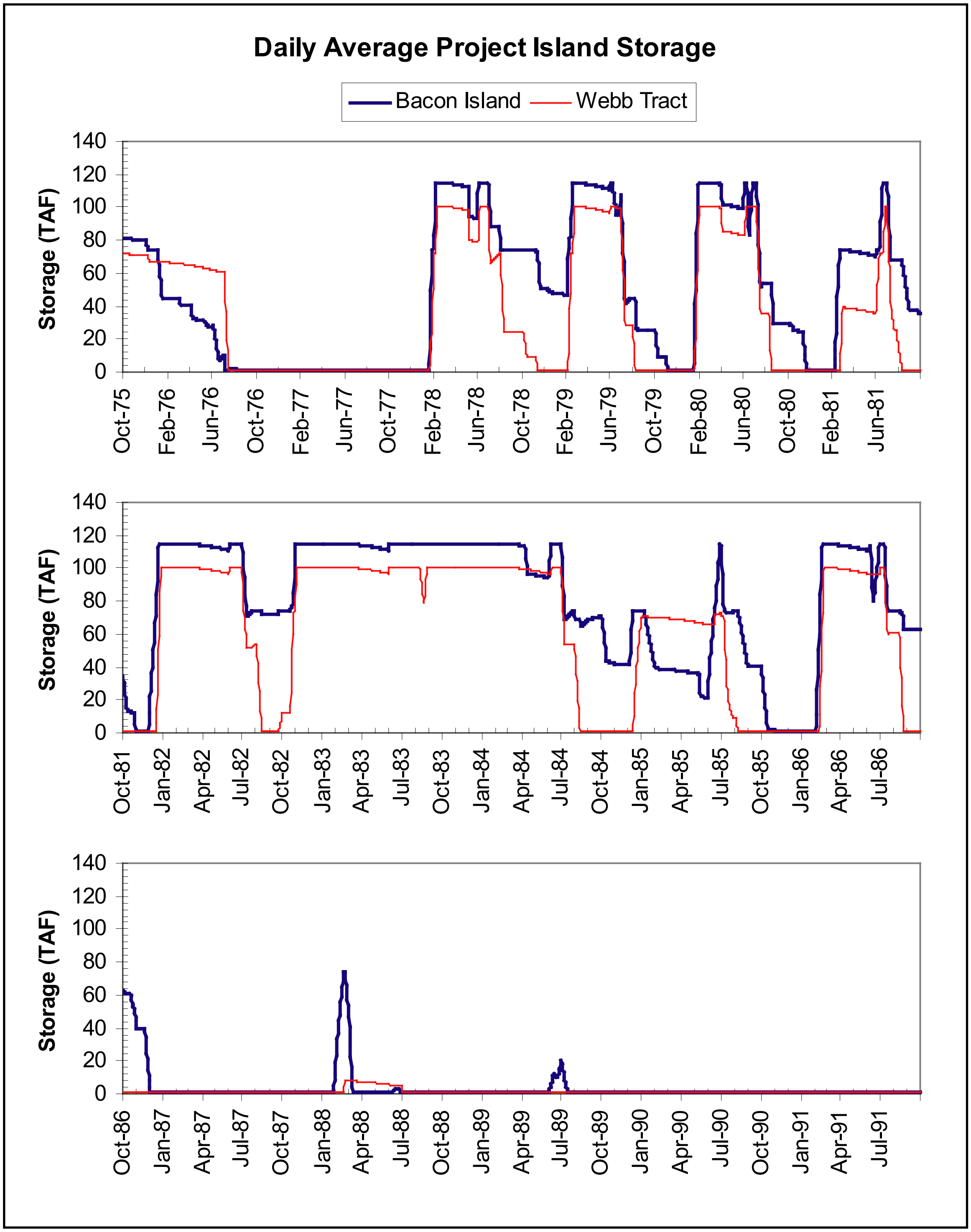

Figure 2.4.6: Daily Average Project Island Storage for Study 4b.

2.4.3 Project Island EC

EC is simulated as a conservative constituent in DSM2. Changes to the EC concentration on the project islands due to a filling operation are a function of both the volume of water already on the island, V_2, and the volume of water diverted to the island, V_4, and the concentrations associated with these volumes, C_2 and C_3, respectively (see Figure 2.4.7). A simple mixing equation is used to blend the concentrations of incoming water with the concentrations of existing water. Since DSM2 is a 1-dimensional model, water inside the reservoirs is assumed to be uniformly mixed.

When there is no diversion into the island, the EC concentration on the island will not change. Although the small evaporation “topping-off” diversions (see *Section 2.4.2.1*) will change the project island EC, the volume of water diverted onto the island is small enough that these changes are minor.

Releasing water from the islands will have no impact on the EC concentration, C_5, inside the reservoirs. However, the concentration in the adjacent channels, C_7, will change. While the volume of water released, V_6, may have a significant impact on the EC concentration in the neighboring channels, the net water added to the Delta itself is small. The impact on local stage should be minor (i.e. storage in the channel should be about the same). The change in local channel EC will be a function based on the amount of water released and the amount of channel water that is not displaced by the project island releases and the respective concentrations associated with both volumes of water (see Figure 2.4.7).

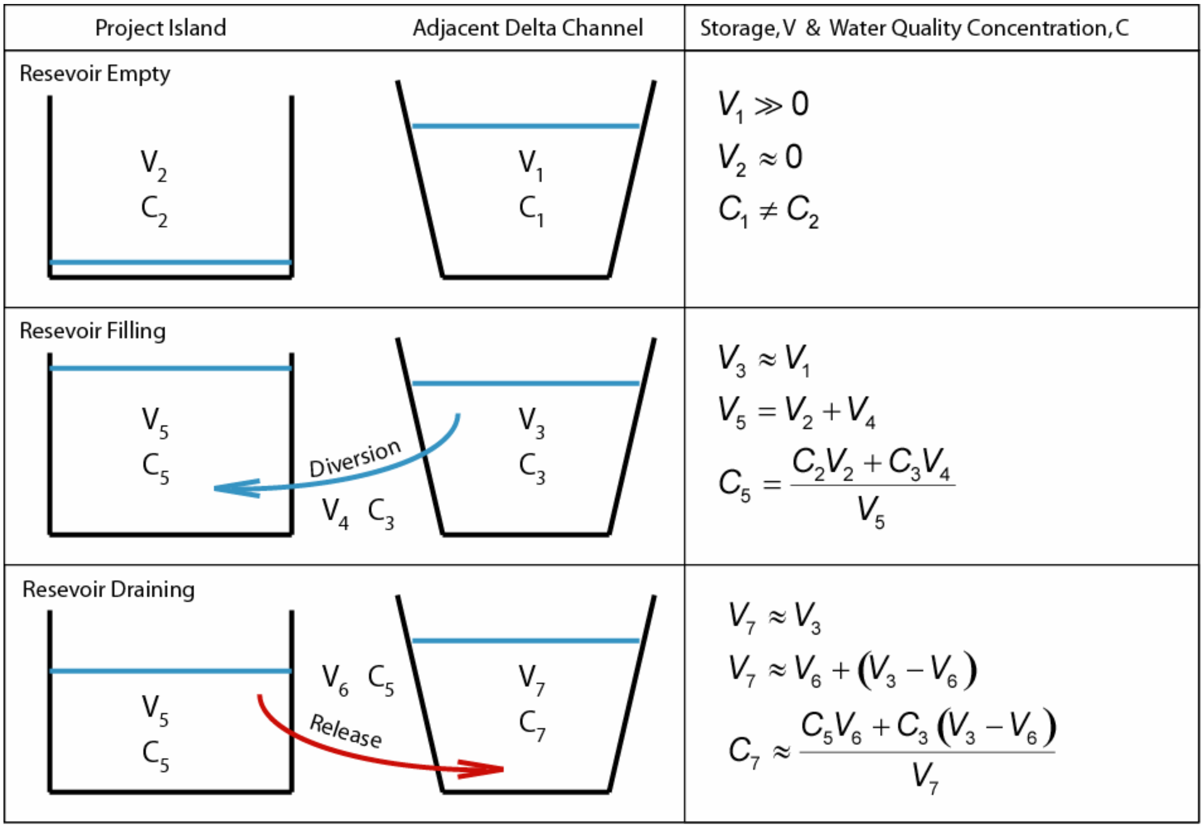

Figure 2.4.7: Mixing Project Island EC with Adjacent Delta Channels.

The EC associated with seepage was determined by running study 4b in an iterative process. In the first QUAL simulation, the EC associated with seepage return flows was set to 0 umhos/cm. The instead of setting EC to 0 umhos/cm, the EC for each island from the first iteration was assigned as the concentration of the seepage return flows. Since the EC concentration assigned to the seepage flows returned to the islands was the same concentration as the water removed by seepage, seepage had no impact on island EC. This iterative process was necessary in order to use the exact same hydrodynamic results that were used when modeling DOC.

The 16-year daily average minimum, average, and maximum EC associated with both project islands is shown in Table 2.4.7. Though the minimum values are similar to the 10% (10^{th} percentile) EC concentrations, indicating that the minimum is a good indicator of what low EC concentrations on the islands would be like, the maximum values are considerably higher than the 90% EC concentration. In other words, there is a greater variation in the higher EC concentrations.

Table 2.4.7: Summary of Project Island EC (umhos/cm) for Study 4b.

Island	Min	Ave	Max	Percentiles				
				10%	25%	50%	75%	90%
Bacon Island	221	402	813	259	316	383	468	560
Webb Tract	186	433	1,101	204	229	349	608	781

The 16-year time series of project island EC is shown in Figure 2.4.8. It is important to note that EC changes only when water (of any amount) is diverted unto the islands.

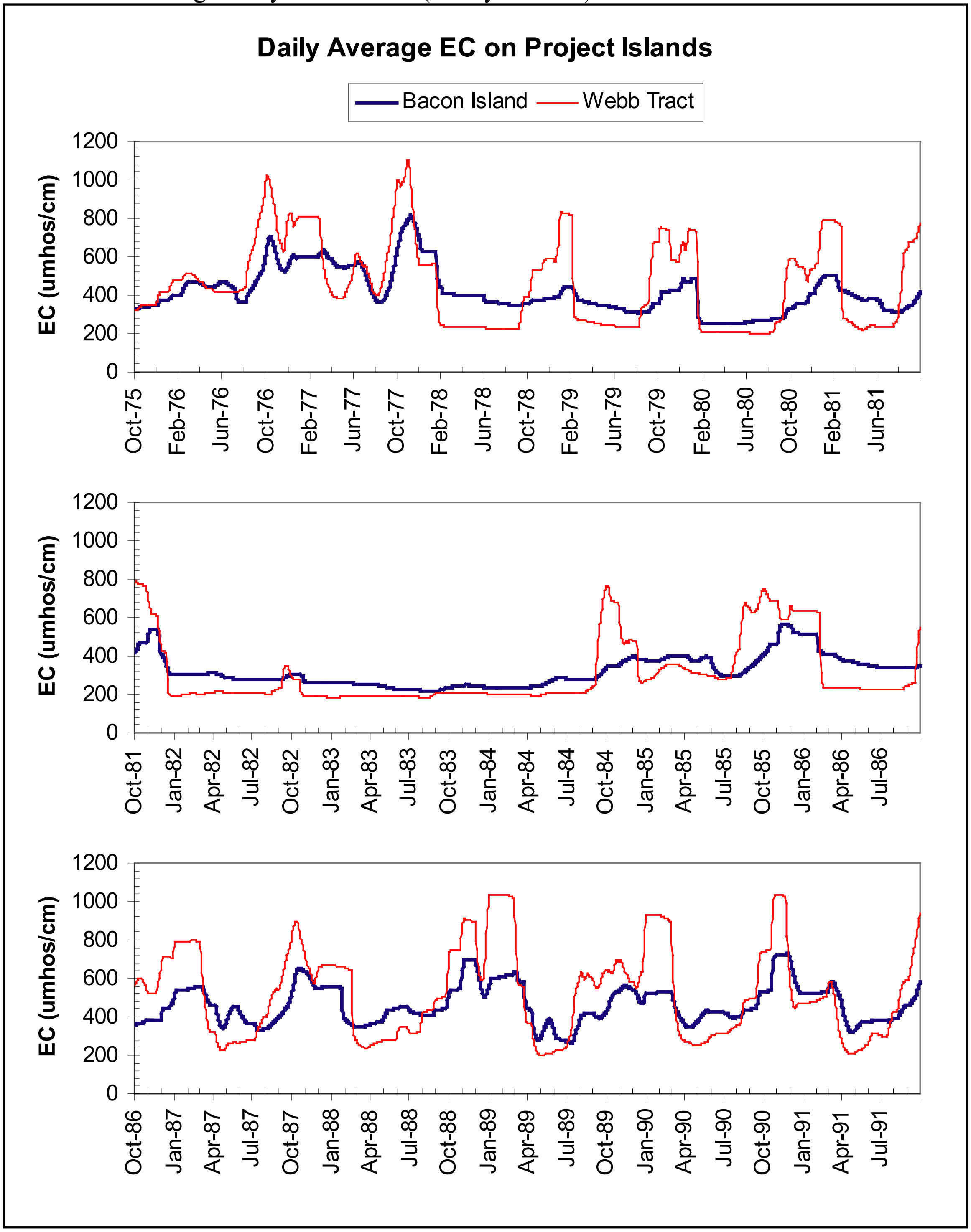

Figure 2.4.8: Daily Average EC (umhos/cm) on Project Islands for Study 4b.

2.4.4 Project Island DOC

Located in the Central Delta, the peat soils from both Bacon Island and Webb Tract are a significant source of the high DOC concentrations of the agricultural returns common to all of the DSM2 water quality simulations. Agricultural return DOC concentrations from both islands can exceed 30 mg/L (Jung, 2000). The principal source of this organic carbon is the peat soils that line the bottoms of both islands.

Storing water on these islands will not only increase the amount of water that comes into contact with the organic carbon rich soils, but as the stored water mixes with the soils, additional organic carbon may enter the stored water through leaching and microbial decay of the saturated peat soils (see Figure 2.4.2). Jung (2001) reported on impact on organic carbon related to flooded Delta islands and conducted new experiments using peat soils from both Bacon Island and Webb Tract. Jung's work suggested that understanding and modeling the processes involved in flooding a peat rich island were important.

The concentration inside either island is both a function of the mixing associated with diversions to the islands (similar to how EC is mixed), the production of organic carbon mass from algae and wetlands plants, and the addition of organic carbon mass due to leaching and microbial decay of the peat soils. The increase in DOC concentration associated with storing water on the peat soil islands is accounted for in QUAL by a DOC growth algorithm (Mierzwa *et al.*, 2003). These relationships are based on field studies conducted by DuVall (2003) that took into account both the increases in organic carbon mass due to decay and leaching as well as the increases due to production of new organic carbon from algae and wetland plants. The organic carbon growth rates, shown in Table 2.4.8, vary over the course of the year.

Table 2.4.8: Project Island Organic Carbon Growth Rates (gC/m2/day)

Island	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Bacon Island	0.59	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.35	0.35	0.59	0.59
Webb Tract	0.59	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.35	0.35	0.59	0.59

In study 4b, seepage flows passed through the organic carbon rich peat soils and were returned to the project islands using interceptor wells. The DOC concentrations of these seepage returns represent the amount of organic carbon that would be entrained in the seepage flows and moved back onto the islands. No direct field tests have been conducted to separate out which organic carbon sources contribute to seepage return quality. Instead of using the same iterative approach that was used when modeling EC seepage return quality, it was assumed that the DOC concentration associated with the seepage return flows was 20 mg/L. It is important to note that seepage only occurs when the stage in an island is greater than -1 ft. At times the DOC concentration of water on a project island is greater than 20 mg/L, and at other times the DOC concentration is less than 20 mg/L. The significance of this assumption can be ascertained by examining the organic carbon concentration on the project islands and the amount of water passing through the interceptor well system.

A summary of the DOC on both project islands for study 4b is shown in Table 2.4.9. The 16-year time series of project island DOC is shown in Figure 2.4.9.

Table 2.4.9: Summary of Project Island DOC (mg/L) for Study 4b

Island	Min	Ave	Max	Percentiles				
				10th	25th	50th	75th	90th
Bacon Island	3	27	337	5	9	13	32	57
Webb Tract	2	28	273	4	7	11	37	70

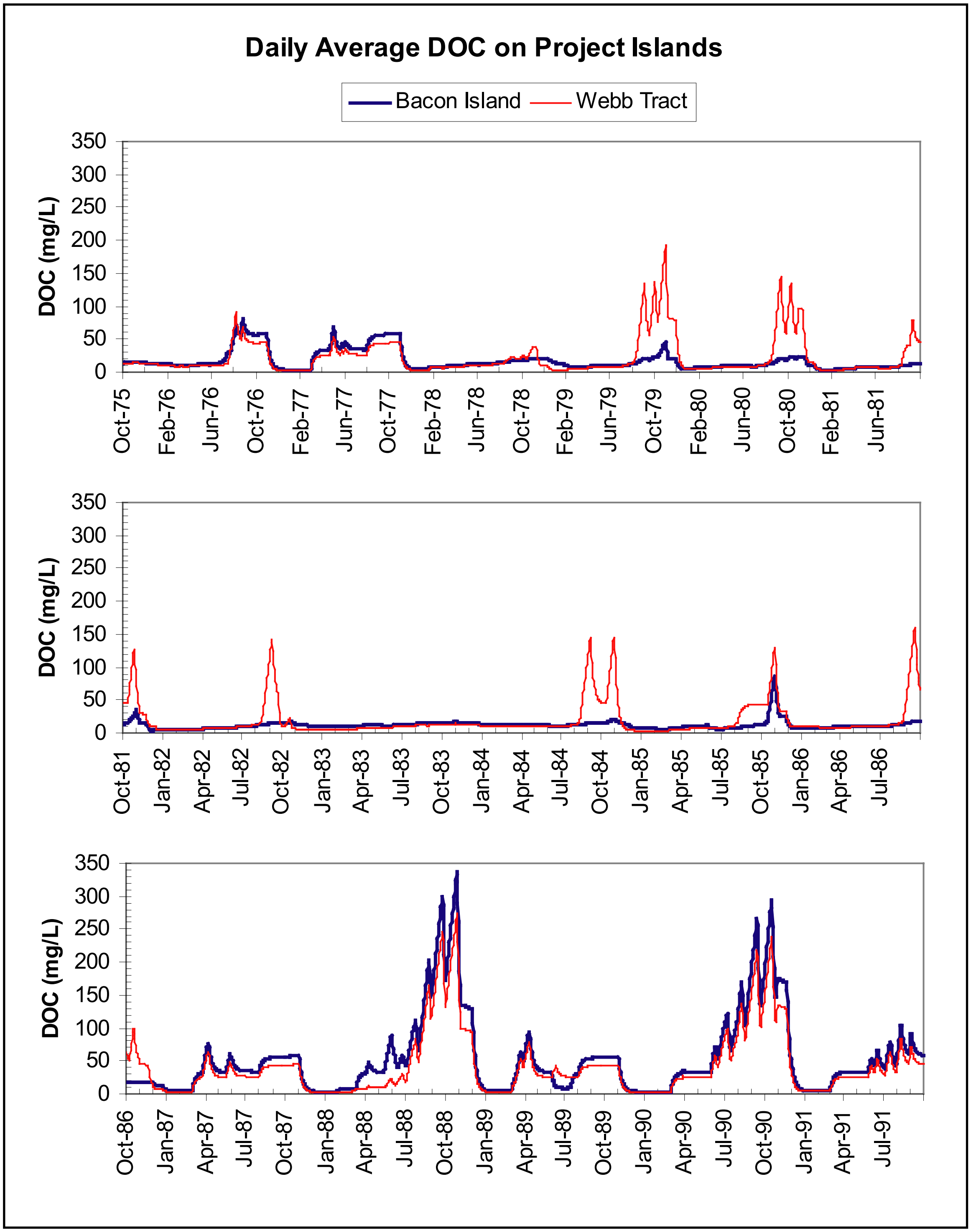

Figure 2.4.9: Daily Average DOC (mg/L) on Project Islands for Study 4b.

2.5 Results

Using the DSM2-QUAL fingerprinting, EC, and DOC results, the change in water quality at four Delta urban intakes: CCWD intake at Rock Slough, CCWD Los Vaqueros Reservoir intake on the Old River, SWP Banks Pumping Plant, and CVP Tracy Pumping Plant, was evaluated. The fingerprinting results were used to develop DOC constraints in CALSIM II. They also provide insight into the internal flow patterns in the Delta. Chloride concentrations at the urban intakes were calculated based on observed EC-chloride regressions. DOC at the intakes was reported as simulated, but then DOC and EC were used to calculate total trihalomethane (TTHM) and bromate formation.

2.5.1 Fingerprinting

Prior CALSIM / DSM2 IDS studies made use of DSM2's ability to track particles through DSM2-PTM to develop flow based DOC constraints in CALSIM II (Mierzwa, 2003). Based on conclusions made during the testing of the previous island-particle fate relationships, a new methodology for estimating the amount of organic carbon reaching the urban intakes in CALSIM was developed.

As described by Anderson (2002), fingerprinting can be used in DSM2 to estimate the original sources of water at a given location. A fingerprinting simulation was set up using study 4 where the diversions to the project islands were treated as a sink of water much like an export, and the releases from the project islands were treated as new sources of water much like a river inflow to the Delta.

Each of the inflows into the Delta, including the Martinez stage boundary and releases from each project island, was assigned a unique conservative tracer constituent and then simulated in QUAL independently of the other boundaries. The amount of water from the Sacramento River, San Joaquin River, Bacon Island and Webb Tract combined, and all other sources at the four urban intakes is shown in Figures 2.5.1 –2.5.4. As expected, the relative contribution of the San Joaquin River water is both a function of time of year and proximity to Vernalis. The fingerprinting plots also illustrate the length of time that water released from the projects remains in the vicinity of the urban intakes. For example, though the Feb. 1988 Bacon Island release ended on Feb. 20th, 1988, a measurable fraction of the water moving through the CVP Tracy Pumping Plant (Figure 2.5.4) came from the project islands.

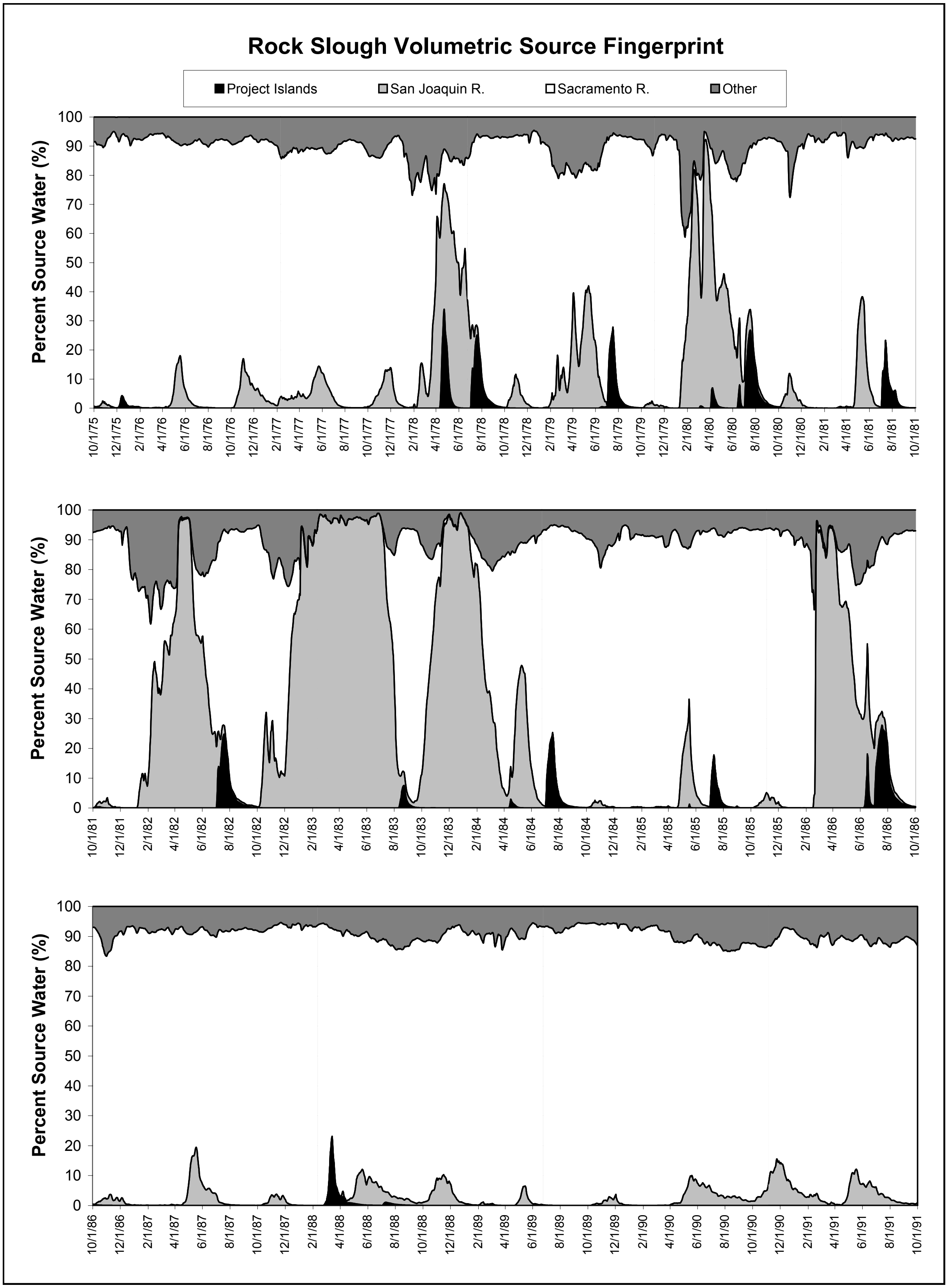

Figure 2.5.1: Old River at Rock Slough Volumetric Source Fingerprint.